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Duriron--An Achievement in Chemical Engineering Materials of Construction

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Chemical phenomena is so all pervading upon the earth, and even throughout the known universe, that the science of chemistry throws its students into contact with the widest diversity of human interests and human needs. It is one of the rewards of an interest in chemistry that it gives opportunity for service to mankind at almost every turn. The applications of chemistry are therefore as diversified as the needs and interests of the race. In illustration of this one need only refer to the ever increasing use of chemistry in chemical manufacturing whose products minister to man's needs from agricultural fertilizers to the varnish on our furniture, from the dyes and treatments to the very fabric of our clothes and textiles, from the rubber of our autos to the metal of all of metal that we use as well as our concrete, our road binding materials and endless other present day needs. These direct uses of chemistry in chemical manufacturing are but a portion of the benefits we derive from an increasing attention to the application of chemical thought in the solution of the problems of the welfare of mankind. There is an increasing demand for the application of chemistry to research in medicine and its clinical problems. The application of chemistry in agriculture is well developed and ever expanding. In brief, chemistry is being applied on all our problems from food, clothes, shelter and transportation to light in our tungston lamps and to comforts without end.

Of the great field of applied chemistry we are for the time in this article interested in what is sometimes called the industrial chemical portion of the field. By industrial chemistry we mean the application of chemical phenomena in the attack upon problems of chemical manufacturing — merely one portion of the domain of applied chemistry. From what has already been said however, it is evident that this single subdivision, industrial chemistry, is a very broad and intricate field in itself. Among other complications there exists within it or rather there is applied to the solution of its problems and the carrying out of its tasks not only efforts at the utilization of chemical phenomena for the solution of its problems, but a great deal of engineering is also utilized for these purposes in the field of industrial chemistry. The chemical industries call on engineering very freely in the solution of these problems. A large portion of this is in that portion of the field of engineering known as chemical engineering.

By chemical engineering we understand that division of the field of engineering which has to do with the operation of chemical production or manufacture. As the youngest educationally of the fields of engineering, it is sometimes misunderstood, particularly by chemists who do not serve. A new handling technique must be de- understand engineering principles and who confuse chemical engineering with applied chemistry. Sometimes engineers fail to sense the influence of chemical phenomena upon simple engineering operations which makes quite real engineering problems of evaporation, distillation, calcination, crystallization, filtration and many other operations which are distinct from all other engineering problems and therefore are in fact chemical engineering. Such a little thing as changing a pump from handling water to handling fairly strong nitric acid takes this transportation problem out of the field of mechanical engineering into that of chemical engineering. At once the highly developed mechanical engineering materials of construction fail to volved or new materials of construction discovered.

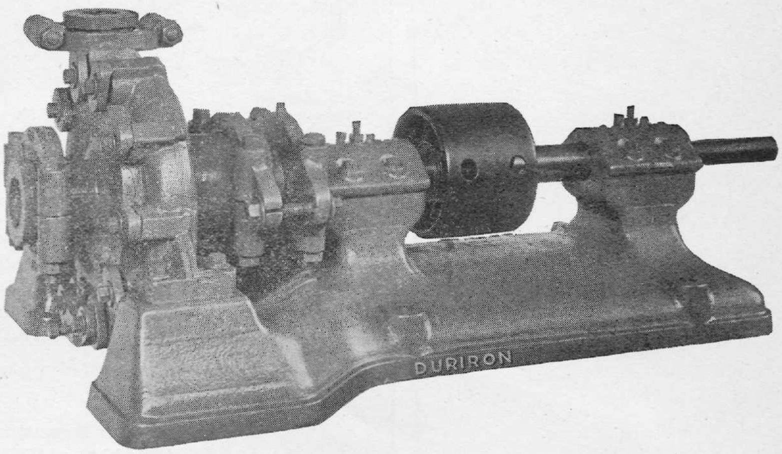

Fig. 1

Materials of construction are of importance in all branches of the field of engineering. They evidently are of paramount importance at times in chemical engineering. Many chemicals and their mixtures require different materials for handling and containing them than others. The whole course of engineering and manufacturing will often depend upon this one factor, though it is but one feature of chemical engineering. In fact, materials of construction furnish a rather minor portion of the problems of chemical engineering. Like other minor details however it becomes paramount at times.

One place where materials become a dominating factor is in the handling of acids, either cold or hot. Dilution is often important. Sulphuric acid, if the more dilute strengths and cold, requires lead. With strong acid lead will not do, but iron or steel will serve. When hot, however, iron has distinct drawbacks. When we come to nitric acid, the problem of handling sulphuric acid dwindles into insignificance. Nitric acid dissolves lead with violence. Iron and most steel equipment is similarly destroyed except under rather restricted conditions. As a result nitric acid as such is only stored in glass or stoneware. Until within ten years condensers and auxiliary equipment were also of either glass or stoneware. Obviously engineering manipulation was seriously handicapped by these considerations of materials. Production too was limited because our sizes in glass and stoneware were quite small as tonnage considerations.

Considerable research and development was therefore directed for years at this problem. It was the neck of the bottle in nitric acid manufacture. Both chemistry and metallurgical methods were applied. Eventually there were developed two solutions, the products "duriron" and "vitreosil." The latter was a fused quartz and therefore still limited in dimensions though most unusual in its acid resisting qualities. It is attacked by hydrofluoric and hot phosphoric acids only.

Duriron was a silicon-iron alloy of rather high silicon content (14%). Its analysis shows—manganese, about 0.35%; total carbon, 0.20-0.60%; phosphorus, 0.16-0.20%; and sulphur, under 0.05%.

Duriron resistivity to corrosion is shown by the results of exposure to various chemical solutions or exposures during the preparation of insoluble compounds of industrial importance. Loss by corrosion follows:

1 year in 25% sulphuric acid,	.179 of 1% loss.
1 year in 25% nitric acid,	.155 of 1% loss.
1 year in 25% acetic acid,	.015 of 1% loss.
1 year in copper sulphate,	.010 of 1% loss.

Exposures of various duration of Duriron to the following showed NO LOSS:

Ammonia
Ammonium Hydroxide
Arsenate of Lead
Arsenious Acid
Sulphate of Alumina
Boric Acid
Picric Acid
Calcium Chloride
Sodium Chloride
Calcium Carbide

PHYSICAL PROPERTIES OF DURIRON

Specific gravity, 7.00.
Weight per cubic inch, 0.253 lbs.
Melting point, 2300 degrees Fahr.
Coefficient of expansion, .00001565 per deg. Fahr.
Electrical conductivity, 1/40 that of standard annealed copper.
Thermal conductivity, 10 times stoneware or quartz.
Contraction allowance in casting, 3/16 inch per foot.
Tensile strength, about 10,000 lbs. per sq. in.
Transverse strength, 1000 lbs. with deflection 1/16 to ⅛ in.
Compression strength, 70,000 lbs. per sq. in.
Shore cleroscope hardness, 49-51.

The cuts illustrate in the case of Fig. 1 the use of Duriron in the construction of a centrifugal pump. All parts which come in contact with the liquid to be pumped are made of Duriron. All mechanical parts which can be attached to Duriron out of contact with the liquid to be pumped are made of other structural materials for the sake of their strength and wearing advantages. Because of the nature of this high silicon iron alloy, the design and construction of these pumps present many additional problems to the usual problems of design of centrifugal pumps. The material is heavier as a rule, and the severe shrinkage conditions during casting also have an effect upon design. It must be admitted that the successful design and manufacture of a centrifugal pump from material of this nature is a distinct engineering achievement. This is true of the many other devices made of Duriron, especially when one considers that the material is too hard and brittle to machine in the ordinary way. All machined parts, even threaded parts, are made by a special developed machine shop technique which is carried out entirely by grinding with carborundum wheels. Otherwise this material would have limited chemical engineering use. Professor Demorest's experimental gas plant uses a Duriron pump for sulphuric acid circulation in connection with ammonia absorption. It is at the east end of the room.

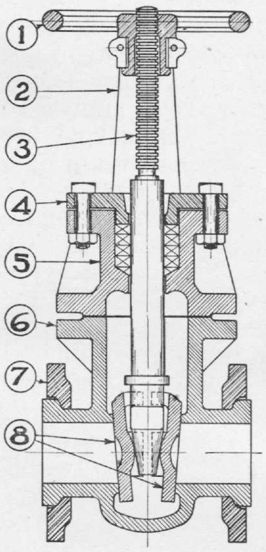

Fig. 2

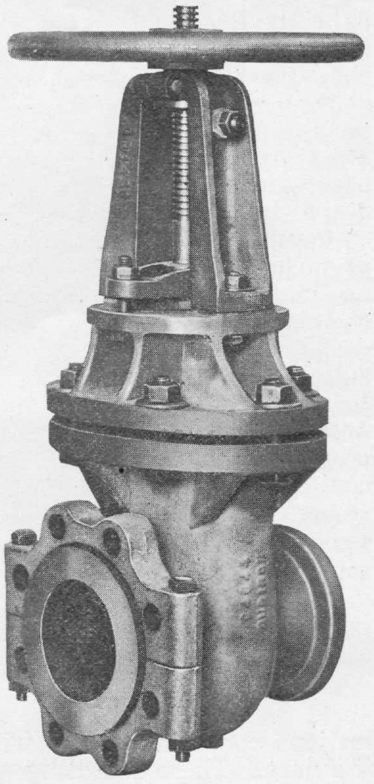

Fig. 3

Much of the success of the design of these pumps is due to Mr. Jacobson, the Designing Engineer of The Duriron Company. Mr. Jacobson was educated abroad as well as in this country, and has had many years experience in the design of pumps before attacking the higher silicon alloy design problems. Mr. Jacobson is an enthusiast for the application of his physics and calculus, in fact, he says he had four years of calculus when he was a student.

Cut No. 2 illustrates a gate valve, all the parts of which are made of Duriron where they come in contact with the liquid to be throttled. This shows clearly how well this material can also be used in this kind of complicated design.

Cut No. 3 is a half-tone of a Duriron gate valve showing the heavy character of the construction and how well and how much the design has been simplified. The method of flanging the valve in the line is shown by means of the split flanges,—one on the valve and the other lying beside it.

The fourth and last cut is a half-tone of a radiation unit made completely of Duriron with the exception of the steel rods which run through the unit at either end to clamp it together. The nuts and head of these bolts are also of the usual steel construction. They, however, are contained in a channel in the Duriron which is independent of the channel through which the liquid flows. They are also encased externally at the ends by means of Duriron caps threaded on the Duriron projection surrounding the bolts, so that neither internally or externally can these steel portions come in contact with corrosive liquids or fumes. These radiating units are finding extensive use in the cooling of sulphuric acid and other hot corrosive liquids, either by circulation therethrough, or immersion in a liquid bath to be cooled. They can also be used as a heating device for raising the temperature of corrosive liquids or solutions.

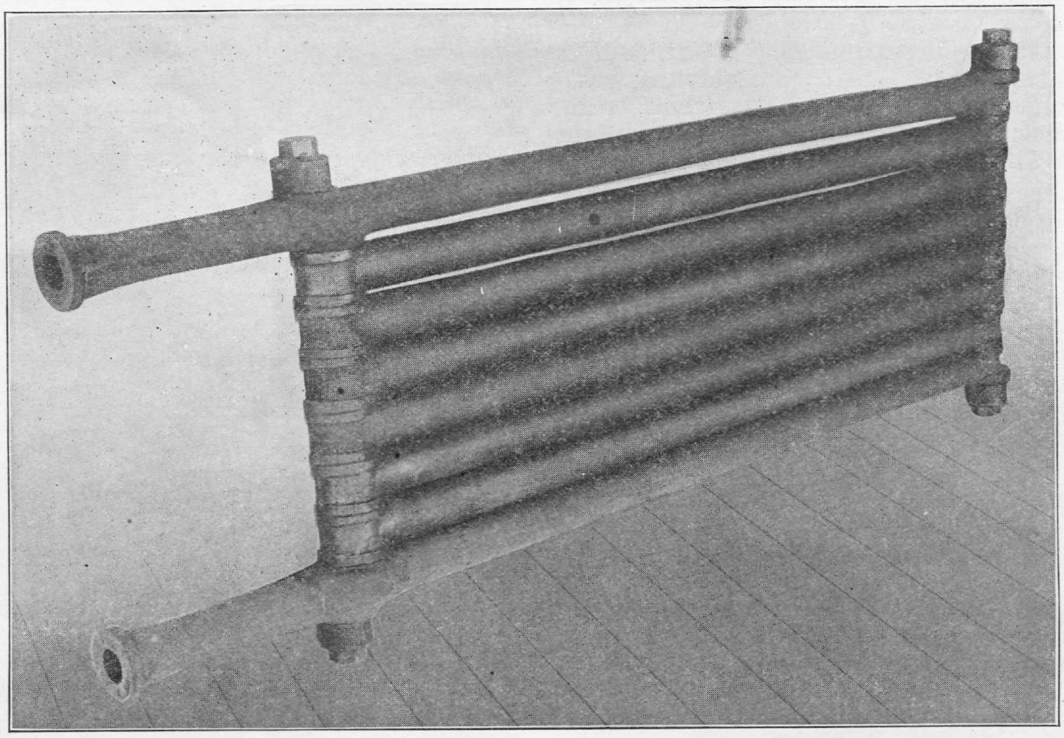

Fig. 4

It is evident that the physical and chemical properties of Duriron are such as to render this material widely useful in chemical engineering work in the manufacture of many corrosive chemicals. Without going into details this fact can be emphasized by reference to its importance in a single war problem out of a number which might be cited.

No one material was of such importance in stemming the German onslaught as the high silicon iron alloy, of which Duriron is the most successful type made in America, for Duriron is an Ohio product developed in Dayton.

Its war service was a simple matter. From the very first of the recent German war high explosives were consumed at a rate vastly greater than any plans of the military staffs on either side. High explosives are derivatives of nitric acid. Several years before 1914 the safe storage of smokeless powder had been perfected. Germany was thus given the opportunity to build up a propellant explosive reserve for any military program she might adopt. She could be prepared if she made the required investment. This was demanded by any offensive program for the reason that nitric acid required for manufacture of explosives was made in plants of peculiarly limited engineering features if the acid was to be made from Chili saltpeter. This was the only source of nitric acid developed on any scale outside of Germany with the exception of the Norwegian development. This latter dwarfed to insignificance under war demands.

War obviously threw upon the chemical engineers of the allied countries an instant demand for extensive new construction in nitric acid plants, complicated by much other new construction. Had the German attack come ten years earlier, it would not have been possible for chemical engineering, as far as we can see, to have furnished a tithe of the needed new nitric acid construction. As a result, Germany's superior explosive reserves placed her in such a position that the sacrifices of millions of brave French and British and Russian lives would have merely staved off for but a few weeks complete success of German arms.

This terrible denouement of the struggle on the continent would have been but the preliminary trial test of the world's greatest military machine. Whether the Germans could have crossed the English Channel is another kind of question. The imagination quails however when one thinks of the possibilities had the German high command developed a higher quality of imagination than it seemed to possess during the actual struggle. Our turn would of course have arrived after that of Britain. No wonder the Kaiser said, in the summer of 1914, his opponents "could afford to wait" — he could not. He was prepared — they might reach the same state of preparation efficiency.

Just where was the limitation that rendered the already high state of development of chemical engineering impotent before this emergency? It lay in one spot — materials of construction. These were reasonably satisfactory for ordinary industrial requirements — but they were being pushed to their limitations in ordinary nitric acid manufacture. These were much of an annoyance to the operating engineer or industrial chemist. Breakage under most careful operation caused loss of time for replacements or required maintaining heavy stocks of replacement equipment. This very care greatly reduced the output per unit of plant.

Ten years before the war few plants used more than 600 lbs. of nitrate of soda per charge, and this was so carefully run as to make more than one charge per 24 hours realized in but few plants, if any. The slow running was necessary lest foaming over project acid — sulphate of soda into the stoneware and glass condenser parts. This would cause direct breakage or eventual breakage in dismantling them for clearing. In normal times the stoneware required for manufacture a minimum of a month at the least. This was because of the clay handling, forming, drying, burning and cooling. Then, too, perfection is not always the result. Much ware comes from the kiln imperfect. When the war broke out deliveries of chemical stoneware jumped to nine months. This alone was a handicap which throttled possibility of new construction and nitric acid in increased quantities became impossible if we had been forced to lean upon our earlier practice of using stoneware.

Notwithstanding this we were not actually so left in despair. We did get the nitric acid and by the old standard methods, for we devised or developed no new methods and we did without stoneware in large part. How? Well, it seems that the all too common business of getting one's heart-desire, because we are in a position to do so, because the other fellow has not the power to resist us, which we see nearly every day, was booked for a shining reverse so that all the world might see and take example. Germany, in spite of the great and good things she had stood for, had permitted herself to be managed by men deliberately determined to get what they wanted for no reason except that they were (as they believed) in a position to take it. In the providential scheme of things however their plans were upset. Many things contributed to this but none of them more emphatically and more seriously than the simple little detail of the arrival of the new chemical engineering material represented by Duriron.

For several years before 1914 there had been much research to develop such a material and a few years before the war there was developed for this purpose in Great Britain this high silicon iron-alloy. It strongly resisted corrosion by nitric acid and it possessed the great war time asset (then of unsuspected importance), i. e., it did not require one month (or later nine months) to duplicate. It could be cast like cast iron — over night, so to speak. Therefore when the Allies first in France and Britain, and finally in our country, expanded and expanded their nitric acid program there was never a falter in the building of new nitric acid plants. And they were such plants! The like had never been seen. They were monsters for size. Duriron had just before 1914 been adopted for "Goose-necks" to handle vapors from the retorts and for uprights and horizontals, on condensers and for bleach-pots. Limitations of size had disappeared as had limitations of time of fabrication. The limit on charge in the retort had been thereby also removed. Foaming over was still undesirable but not so serious in its consequences.

To make a long story short, we had acquired sufficient experience by 1914 that the designing chemical engineer could throw his age-long conservatism to the winds and design plants for high speed, heavy duty production. He no longer had "ginger bread" fixtures of stoneware. The new war time plants had hundreds of retorts which held 6000-8000 lbs. of nitre to a charge with an equal amount of sulphuric acid. These retorts operated with the very minimum of head room for foam-over. If there was a boil over a hammer would break the brittle Duriron "goose-neck" on the top of the still and permit it to vomit or vent itself without plugging the condensers. Then in an hour a new goose-neck could be in place instead of a week or longer delay with stoneware. This therefore permitted rapid operation and the stills were "turned" not once but three times in 24 hours. The increase in production per 24 hours by these various changes was stupendous and *explosive manufacture did not fail us.* All this was not "just ready to go when armistice came," it was in full swing even in the United States *many months before we entered to war in 1917.*

The simple little co-operative metallurgical and chemical engineering research on corrosion-resisting alloys was never intended to save the lives of nations or even of individuals, let alone perhaps millions of them. The most humble research or engineering development may be an unsuspected blessing of the greatest value to mankind. Statesmen and even well informed citizens could not be expected to prize the minor field of materials in chemical engineering as of any great national importance. The same may be said of any other advance in science or engineering. This is merely another emphasis on the gospel of long ago: "The eye cannot say unto the hand, I have no need of thee." . . . . We have need of and should encourage research however seemingly unimportant, which can in any way be thought of as spelling "Help," for some may need that help when least expected. It is probable that history seldom puts her finger on the vital spot that made disaster possible. Let us never forget in our own work that it is to the credit of engineering that it is "Help" personified.